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EFFECT OF FRUIT MATURITY ON EFFICIENCY OF POLYAMINES TO DELAY THE RIPENING OF GUAVAS UNDER COLD STORAGE

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ABSTRACT

Fruit firmness, skin colour, percent ripening, percent spoilage, shelf life, organoleptic quality, respiration and ethylene evolution rates were monitored during cold storage (10±1°C and 90±5% RH) in guavas (cv. Lucknow-49) harvested at two stages of maturity, Mature Green (maximum growth of fruits is attained and skin colour changes from dark green to light green) and Colour Turning (skin colour turns slightly yellow from light green) treated with Polyamines (PAs) viz., Spermidine (100 and 200 ppm) and Spermine (100 and 200 ppm). Irrespective of maturity stages and PAs studied, fruit firmness decreased while skin colour (Hunter 'L', 'a', 'b', hue angle and chroma values), ripening and spoilage percentages increased progressively with the advancement of storage period. Likewise, respiration and ethylene production rates also exhibited similar pattern of increase, coinciding with ripe stage followed by a decline later. However, the peak in respiration rate was preceded by maximum ethylene production in guava during storage at 10±1^{0}C. Mature green (MG) stage fruits in combination with all the Polyamine treatments showed promising results in extending the shelf life and delaying the ripening related changes (particularly skin colour) compared to colour turning (CT) stage during cold storage. Among the PAs, MG fruits treated with Spermine (100ppm) recorded a shelf life of 24.33 days with moderately acceptable fruit quality.

KEYWORDS: Lucknow-49, Mature Green, Colour Turning, Pas, SPD, SPM, CO_2 and C_2H_4

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Original Article

INTRODUCTION

Guava (*Psidum guajava* L.) is an important tropical and sub-tropical fruit crop which is grown widely in India. It is the fifth most widely grown fruit crop after banana, mango, citrus and papaya in India and occupies an area of 0.26 million hectares producing 3.66 million tonnes with an average productivity of 13.7 MT/ha (Saxena and Gandhi, 2014). The fruits are delicious, rich in vitamin 'C', pectin and minerals like calcium, phosphorous and iron. Guava fruits are used as fresh as well as for making jam, jelly, nectar, paste *etc*. (Boora, 2012). There is a great demand of guava fruits in both domestic and international markets for fresh and processing purposes. The share of guava in fresh fruit export from India is mere 0.65 per cent which can be further boosted, if fruit is properly handled after harvest to earn more foreign exchange (Mitra *et al*., 2008). Guava is a perishable fruit and highly prone to bruising and mechanical injuries. Due to such perishability, control of fruit ripening is fundamental and this generates the necessity to search for new technologies to increase shelf life, reach distant markets and thus improve the marketing process (Mitra *et al*., 2012). Skin colour is the best maturity index in guava (Mercado-Silva *et al*., 1998; Kader, 1999 and Asrey *et al*., 2008) as it could be monitored non-destructively during fruit ripening and storage. Fruits attaining maturity show signs of

changing colour from pale green to yellowish green. If the fruit is to be shipped to distant markets it should be mature, full sized and of firm texture, but without an obvious colour-break on the surface. Fruits for local market can be harvested in a more advanced stage of maturity (Singh, 2007). However, harvesting fruits at appropriate stage of maturity is critical in maintaining the post harvest quality of guava fruits (Azzolini *et al*., 2004 and Patel *et al*., 2015).

Storage under low temperatures has been considered the most efficient method to maintain quality of most fruits and vegetables due to its effects on reducing respiration rate, transpiration, ethylene production, ripening, senescence and disease incidence. On the other hand, enzymatic reactions occur slowly at low temperatures, extending shelf life of perishables (Bron *et al*., 2005). In climacteric fruits, like most guava varieties, the reduction of temperature delays the climacteric peak and consequently, ripening process (Paull and Chen, 2002). Of late, a new group of compounds namely polyamines (Putrescine, Spermidine and Spermine) have been implicated in wide range of plant growth and developmental process including delaying of senescence (Galston and Kaur-Sawhney, 1995). The involvement of polyamines in extending the shelf life of grapes was demonstrated by Reddy *et al*. (2008a & b), Ahmed (1998) in mango and Bhagwan (1998) in tomato. Taking into consideration the domestic demand, export opportunities and the expansion of processing sector, it is evident that there is vast scope to promote cultivation and improve productivity of nutritionally rich fruits (Singh, 2006). To achieve these goals, the management should be significantly geared up to meet the challenge of handling huge produce, while maintaining the natural quality of the produce. It is axiomatic that quality of produce cannot be improved but it is possible to slow down the rate of undesirable changes and, thus maintaining quality. Keeping these facts in view, a comprehensive study was carried out at Post Harvest Technology Laboratory, College of Horticulture, Rajendranagar, Hyderabad during the Nov-Dec (2010), on various ripening related changes in guava cultivar 'Lucknow-49' fruits to determine appropriate maturity stage and postharvest treatment for better quality and desirable shelf life under cold storage.

MATERIAL AND METHODS

Material: Uniform medium sized guava fruits apparently free from diseases and bruises were harvested at two stages of maturity. Mature green stage (MG) is when maximum growth of fruits had been attained and their skin colour changes from dark green to light green; colour turning stage (CT) is when the skin colour turns slightly yellow from light green. They were divided into prerequisite lots for further handling.

Postharvest Treatments, Packing and Storage: The experiment consisted of three replications and 10 treatment combination. For each replication, thirty fruits (approx. 5Kg) each for MG and CT stages were selected and subjected to treatment with Polyamines. The fruits were dipped in aqueous solutions of Spermidine (100 and 200 ppm) and Spermine (100 and 200 ppm) separately each for 5-10 minutes. The control fruits were dipped in tap water for 5-10 minutes and kept for comparison. The surface of the fruit was air dried and thereafter packed in newspaper lined Corrugated Fibre Board (CFB) boxes of 400/300/140 mm size, 3 ply thickness, 4.5Kg capacity with 5 percent ventilation. The fruits were stored in walk-in cold chamber (Quality Control Laboratory, ANGRAU, Rajendranagar, Hyderabad) maintained at 10±1°C temperature and 90±5% relative humidity.

Analytical Methods: Fruit firmness was measured on opposite sides of the equatorial axis using a stand penetrometer of 0-20Kg scale (Deccan Techno Corporation). A plunger of 6mm diameter was used for the determination of rupture force and the readings were expressed as kg/cm^2. Skin colour of guava fruits was instrumentally determined by using a colorimetric spectrophotometer (Model: Colorflex XE, Hunter Lab, West Virginia, USA) and expressed in Hunter scale ('L', 'a', 'b', hue angle and chroma). The readings were made at three equidistant points of the equatorial axis of

fruits. Hunter 'L' data indicates lightness of the object, range between 0 (black) and 100 (white). The 'a' data represents red and green: positive values indicate red colour with +60 being the maximum, while negative values indicate green colour with -60 being the maximum and 0 is considered neutral. Similarly, 'b' represents yellow and blue: positive values are yellow, while negative values are blue and 0 is considered neutral (McGuire, 1992). Ripening and spoilage percentages were determined by visual observations. Guava fruits with more than 50 percent yellowing of skin colour were counted at specific intervals of storage out of total fruits stored in each replication was computed and expressed in percentage. Similarly, the number of fruits spoiled (unfit for consumption) in each replication was counted at specific intervals of storage out of total fruits stored was computed and expressed in percentage. Fruit samples of known weight and volume were enclosed in hermetically sealed PVC containers (500ml capacity), fitted with silicon Teflon septum, for an hour. The probe of the gas analyzer was inserted through the septum and the gas concentrations of O_2 (%), CO_2 (%) and C_2H_4 (ppm) were recorded directly from the display screen. Respiration rate was determined using O_2/CO_2 gas analyzer (Model: Checkpoint EN, PBI Dansensor, Denmark) and expressed in $mLCO_2/Kg/h$ (Singh, 2006). Ethylene production rates were analyzed using a battery powered portable ethylene meter (Model: Ethan, Bioconservacion, SA) with 0-100 ppm range and expressed in $\mu LC_2H_4/Kg/h$ (Singh, 2006). The storage life was determined by recording the number of days the fruits remained in good condition without spoilage in each replication during storage. When the spoilage (over-ripening, skin browning and rotting) of fruits under different treatments exceeded 50 percent, it was considered as the end of storage period which was judged by visual scoring. The overall organoleptic rating of the fruits was done by a panel of five semi-trained judges on the basis of nine-point hedonic scale (9 = Like Extremely; 8 = Like Very Much; 7 = Like Moderately; 6 = Like Slightly; 5 = Neither Like Nor Dislike; 4 = Dislike Slightly; 3 = Dislike Moderately; 2 = Dislike Very Much; 1 = Dislike Extremely) for fruit appearance and colour, flavour, texture and taste (Amerine *et al*., 1965).

Statistical Analysis: There were three replications for each treatment and each replicate was comprised of 30 fruits. The experiment was laid out in Completely Randomized Design (CRD) with factorial concept and the data was subjected to analysis as per the procedure outlined by Panse and Sukhatme (1985).

RESULTS AND DISCUSSIONS

Firmness (Kg/cm^2): Fruit firmness decreased significantly with the advancement of storage period irrespective of maturity stages and polyamines studied Table 1. It ranged between 7.07 Kg/cm^2 on 5^{th} day and 2.22 Kg/cm^2 on 20^{th} day during storage at low temperature. This loss in firmness is generally associated with ripening might perhaps be due to the activities of cell wall degrading enzymes like, PME and PG (Hobson, 1963). Guava fruits harvested at MG stage (5.17 Kg/cm^2) maintained higher firmness values compared to those of CT stage (4.05 Kg/cm^2) throughout storage. Possibly, in early maturity stages the enzymes related to softening were still not completely synthesized and activated (MacRae *et al*., 1989). Among the polyamine treatments, Spermine treated fruits were more firm than Spermidine treatments, because SPM was more effective than SPD or PUT in preventing senescence related events particularly softening (Apelbaum *et al*., 1981, Kuar-Sawhney and Galston 1991). The higher concentration (200ppm) of both the polyamines maintained significantly higher fruit firmness than their corresponding lower concentration. The increase in maintenance of firmness by polyamines could be attributed to the cross linking of polyamines to the carboxylate (-COO-) group of the pectic substances in the cell wall, resulting in rigidification. This binding also blocks the access of degrading enzymes such as PME and PG, thus reducing the rate of softening during storage (Valero *et al*., 2002). The results are in accordance with the ones obtained by Purwoko *et al*. (1996) in papaya and Malik and Singh (2005) in mango, where an increase in the

concentration of PAs concomitantly increased fruit firmness.

Skin Colour (Hunter L, a, b): During storage at low temperature, the Hunter 'L' and 'b' values showed an increasing trend, whereas the negative Hunter 'a' value decreased with increase in days of storage irrespective of maturity stages and polyamine treatments indicating a progressive development of skin colour of guava fruits from green to yellow Tables 1, 2 and 3. There was a significant improvement of yellowness (Hunter 'b') value and skin luminosity or lightness (Hunter 'L') value in both MG and CT stages of guava fruits during low temperature storage. However, the complete loss of skin greenness (Hunter 'a') and yellow colour development was much earlier in guava fruits harvested at colour turning stage during storage. The results were in accordance with Paull and Goo (1983). Thereafter, sudden fall in 'L' and 'b' values was noticed with colour turning stage fruits. This decrease was due to over-ripening and rapid senescence, where the fruits turned dull and yellowish brown in colour. The decrease in negative Hunter 'a' value (greenness) was accompanied by the increase in yellowness (Hunter 'b' value) value. The loss in skin greenness during ripening perhaps may be due to increased activities of chlorophyll degrading enzymes including chlorophyllase, chlorophyll oxidase and peroxidase (Jain *et al*., 2001).

It was also observed that colour development is closely associated with climacteric peak (respiration and ethylene production rates) of both the maturity stages Figure 1. The colour development which started prior to the onset of climacteric was completed at the peak climacteric stage. These colour changes clearly indicate the physiological changes associated with ripening which are desirable in climacteric fruits like guava to improve its marketability. A gradual increase in Hunter values ('L', 'a', 'b') were also observed in other cultivars of guava at three stages of maturity *viz*., mature green, green yellow and yellow (Mercado-Silva *et al*., 1998, Soares *et al*., 2007 and Pradeep *et al*., 2014) and mango (Kudachikar *et al*., 2001) during ripening and storage. The delay in chlorophyll degradation and yellow colour development in fruits harvested at early stage of maturity could be due to the enzymes related to ripening have not been fully synthesized or even inactivated (Lalel *et al*., 2003). Narayana and Mustaffa (2007) also pointed out that banana fruits at 100 percent maturity exhibited colour change faster than fruits of lower maturity. In a study conducted by Basulto *et al*. (2009), maximum gas production (CO_2 and C_2H_4) coincided with the point at which the average a* value of papaya fruits nearly reached zero (*i.e*. no green remains and red begins to appear). However, Brito and Narain (2002) observed the change in skin colour of sapota fruits from green colour in mature stage to brown colour in ripe stage. The yellow colour development was rapid with the untreated fruits and complete degreening was noticed after 10 days of storage. Among the polyamine treatments, Spermine (100 and 200ppm) treated fruits effectively delayed colour development by registering lower Hunter 'L', 'a', 'b', hue angle and chroma values compared to the Spermidine treatments during low temperature storage. These treatments took more number of days for complete degreening over control. This may perhaps be due to retarded production of ethylene, which in turn is being seen as a resistance factor in ripening. It was also observed that higher concentration (200ppm) of both the polyamines studied significantly maintained green colour for prolonged storage than their corresponding lower concentration (100ppm). During different storage intervals, loss in greenness was observed after 10^{th} day and 15^{th} day of storage respectively with the untreated and treated fruits of guava. The retardation of colour development with polyamine treatments indicate lower chlorophyll degradation, carotenoid synthesis and delay in senescence processes. A similar reduction in the colour development of various fruits was noticed with the application of polyamines particularly Spermine in the findings of Purwoko *et al*. (1996) in mango and papaya, Bhagwan *et al*. (2000) in tomato, Malik and Singh (2005) in mango, and Barman *et al*. (2010) in pomegranate with or without any apparent reduction in ethylene production during storage.

Ripening and Spoilage Percentage: The ripening of guava fruits was marked by levigation of surface, evanescence of chlorophyll, development of typical aroma, flavour and taste coupled with textural softening (Singh *et al*., 1990). Guava fruits harvested at mature green stage obtained lowest ripening values compared to colour turning stage Table 4. Similar observations on delayed ripening by harvesting at early maturity stages have been made in different fruits, guava (Reyes and Paull 1995), banana (Krishnamurthy, 1989 and Harris *et al*., 2000) and mango (Lakshminarayana, 1975). According to Trewavas (1982), the quantity of ethylene receptors is reduced in fruits harvested when still green and, for this reason, ethylene-dependent processes like ripening can be delayed. Therefore, the delay in ripening in MG stage during storage in the current study can be attributed to the aforesaid reason. Almost hundred percent ripening was noticed on 15^{th} day of storage under control. However, Spermine treatments effectively slowed down the ripening process compared to Spermidine treatments in the present study. Valero *et al*. (2002) stated that the efficiency of exogenous application of polyamines on retarded fruit ripening was generally greater for those molecules with higher number of cations, that is $SPM^{4+} > SPD^{3+} > PUT^{2+}$. It was also observed that higher concentration (200ppm) of both the polyamines studied significantly reduced the rates of ripening and spoilage of guava fruits for prolonged storage than their corresponding lower concentration (100ppm). The fruits in control and Spermidine treatments were hundred percent ripe after 15 days of storage.

Spoilage of guava fruits was observed in the form of shriveling, over-ripening, skin browning and rotting during low temperature storage. There was a considerable loss due to decay caused by various fungi and inherent biochemical changes such as desiccation and shrivelling (Chundawat *et al*., 1976). In the present investigation, guava fruits in some of the treatments were infected with *Aspergillus* and *Penicillum* rots; blossom end rot (*Phomopsis psidii*), anthracnose (*Colletotrichum gloeosporioides*) and bacteria. However, relatively small amounts of guava fruits exhibited chilling injury symptoms such as skin browning and pitting, generally noticed after 10 days of storage at low temperature with both the maturity stages. The spoilage loss was highest and more prominent in fruits harvested at later stage of maturity Table 4. The highest spoilage in CT stage fruits might have occurred due to increased respiration rate, enzyme activities and dissolution of cell wall which ultimately lead to early softening and over-ripening of fruits. This trend of increased spoilage with increased ripeness is similar to those reported by Juan *et al*. (1999) for apples, Kamil *et al*. (2008) for guavas and Gupta and Jawandha (2010) for peaches. The rate of spoilage of guava fruits increased with increase in ripening and storage irrespective of maturity stages, polyamines and their interaction, as evident from the data. This increase in ripening which is generally associated with increased fruit softening during storage is nothing but a symptom of progressive senescence. All the polyamine treatments led to reduced ripening and spoilage over control during storage at low temperature. Earlier findings of Saftner and Baldi (1990); Rastogi and Davies (1991) postulated that PAs could indeed delay fruit ripening, reduce mechanical and chilling injury. The symptoms of spoilage of guava fruits were observed on 5^{th} day of low temperature storage in all the treatments including control. The lowest spoilage percentage was noticed in fruits treated with Spermine at 200ppm (24.17%), whereas the maximum spoilage was observed in case of control (48.06%), which might be due to higher rate of respiration compared to other post harvest treatments, causing early ripening and high incidence of diseases. Thus exogenous application of Spermine might have increased the endogenous free polyamine levels in treated fruits, possibly reduced ethylene production and hence delayed ripening (Bhagwan, 1998). The reduced spoilage in polyamine treated fruits could be mainly attributed to the retarded fruit ripening, because susceptibility to pathogens increases with ripeness. Similar findings were reported in peach by Martinez-Romero *et al*. (2000), mango by Malik and Singh (2005) and pomegranate by Mirdehghan *et al*. (2007).

Respiration and Ethylene Production Rate: There was a remarkable difference in the respiratory and ethylene production rates of treated and untreated fruits with both the maturity stages during storage at low temperature Figure 1. In the present study, the peak rates of CO_2 production were observed on 10^{th} day and 15^{th} day of storage, respectively, with CT stage and MG stage fruits thus indicating delayed ripening. This delay in respiratory peak with the early harvested fruits may be attributed to delayed colour changes. Previous studies with two guava cultivars (Safeda and Sardar) have demonstrated a respiration peak at yellow hard stage and decline thereafter in ripe stage (Selvaraj *et al*., 1998 and Killadi *et al*., 2007). Fruits harvested at mature green stage showed a typical climacteric respiration and ethylene production pattern at 10^0C, as was reported by Mercado-Silva *et al*. (1998) in guava cv. 'Media China'. However, Azzolini *et al*. (2005) pointed out that 'Pedro Sato' guavas exhibited a gradual increase in respiration and ethylene production, while maximum respiratory activity, as well as ethylene production was observed when the fruits were already ripe. In general, the colour and quality changes coincided with the peak in respiration rate *i.e.* on 10^{th} day and 15^{th} day of low temperature storage with guava fruits harvested at CT and MG stages respectively.

All the polyamine treatments practically reduced and delayed the rate of respiration compared to control. However, the rate of reduction was much higher in case of Spermine (100ppm and 200ppm) treated fruits. Exogenous application of polyamines was reported to increase endogenous pools (Bhagwan, 1998) and externally applied polyamines have been shown to inhibit CO_2 production in the present study. The lower concentration of SPM and higher concentration of SPD were found better in reducing the CO_2 production to a maximum extent, which was also reported by Malik *et al*. (2006) in mango. The maximum reduction in respiration rate was observed with mango fruits treated with 0.5mM SPM as reported by Malik and Singh (2005) also lend support for the findings of the present study. Guava fruits at MG stage showed highest C_2H_4 production than CT stage for a period of 20 days during low temperature storage. A clear evidence of increased ethylene content from green to colour turning stage was reported in guava (Selvaraj *et al*., 1998), which was later confirmed by Mondal *et al*. (2008) and Simrat (2009) where the peak for C_2H_4 production in guava fruit occurred at the half-ripe or colour break stage, thus leading to early softening and spoilage. The results are in close conformity with the above findings, wherein a marked rise in C_2H_4 production was observed on 5^{th} day and 10^{th} day of storage, with colour turning and mature green stages respectively. The fruits in control did not show any prominent peak for ethylene production. This indicates that untreated fruits had already completed climacteric rise in ethylene production before 5^{th} day of storage. The rate of ethylene production was much higher in all the polyamine treatments as compared to control. The untreated fruits showed an early peak in ethylene production after harvest, and followed a rapid declining trend during storage, thus leading to early softening and spoilage. This shows that the PA treated fruits due to retarded ripening for prolonged storage exhibited higher rates of ethylene production on all the days of storage than the untreated ones. The observed difference between untreated and treated in the pattern of ethylene production of guava fruits may be attributed to the fact that polyamines may regulate ethylene synthesis by competing with it for S-adenosyl methionine (SAM), a common precursor for their biosynthetic pathway (Galston and Kaur-Sawhney, 1995) and hence inhibit C_2H_4 biosynthesis (Martinez-Romero *et al*., 2007).

True to these findings, Ahmed (1998) observed a decrease in the endogenous levels of polyamines in mango fruits during ripening with concomitant increase in C_2H_4 production. Wang *et al*. (1993) noticed that C_2H_4 and PAs may interfere with the production and function of one another. They further stated that, the degree of interference may vary with species, type of tissue and the experimental systems used. Contrary to the one above, it was also noticed that ethylene and free polyamines biosynthesis may not be competitive in mango (Malik and Singh, 2004) and apple (Kramer *et al*., 1991).

Polyamines also have the ability to decrease lipid peroxidation in maintaining membrane stability, delay senescence and inhibit ethylene production (Apelbaum *et al*., 1981). The extent to which polyamines inhibit ethylene production depends largely on the stage of fruit ripeness and also the effect was more pronounced at early stages of ripening before C_2H_4 production enters its presumed autocatalytic stage. However, Liu *et al*. (2006) opined that the inhibitory effect on C_2H_4 by PAs occurred at later stage of fruit development. PAs have also been shown to inhibit C_2H_4 production in the reports of several workers, Wang *et al*. (1993) in apple, Malik and Singh (2005) in mango and Franco-Mora *et al*. (2005) in pear.

Shelf Life (Days): In the present study, it was observed that all the polyamine treatments were significantly superior over control in extending shelf life of guava fruits with both the maturity stages during storage at low temperature Figure 2. However, MG stage recorded extended shelf life than CT stage which might be due to a shift in climacteric peak because of delayed physiological and biochemical changes during ripening and the delay in these changes being more prominent in cold storage. Tandon *et al*. (1989) also reported that larger and more mature fruits of guava had shorter shelf life and hence could be transported only to shorter distances. The fruits picked at the later stage of maturity (CT stage) were spoiled due to over-ripening and rotting with minimum consumer appeal during storage. The data is quiet similar to those of Barua *et al*. (2010) in tomato, Narayana and Mustaffa (2007) and Gonge *et al*. (2014) in banana, wherein a decrease in shelf life is noticed with the advancement of maturity. A clear cut evidence of the ability of polyamines in increasing shelf life has been observed in guava fruits treated with Spermine (100 and 200ppm) compared to Spermidine. A similar kind of phenomenon was noticed in various fruits, Bhagwan *et al*. (2000) in tomato, Malik and Singh (2005) in mango, Mirdehghan *et al*. (2007) in pomegranate and Reddy *et al*. (2008a) in grapes.

The difference between SPM and SPD in the extension of shelf life of guava fruits may be attributed to the fact that SPM treated fruits took more number of days for complete ripening and colour development with minimum fruit spoilage. Earlier, Galston and Kaur-Sawhney (1995) opined that Spermine because of its tetra-amine structure has a very high potential in retarding senescence compared to tri-amine (Spermidine) and di-amine (Putrescine). The lower concentration of SPM and the higher concentration of SPD were found better in extending shelf life of guava fruits in the current study. Malik *et al*. (2006) also confronted similar observations in mango, where lower concentrations of SPM and higher concentrations of SPD and PUT were found to be more effective in prolonging the shelf life of fruits. Contrary to the above findings, Ahmed (1998) pointed out that SPM at higher concentration proved best in maintaining better keeping quality and maximum shelf life in mango. However, explaining the discrepancies among the results from various studies is rather difficult.

Sensory Rating (9 Point Scale): The effect of maturity stages and post harvest application of polyamines showed significant differences with respect to fruit appearance and colour, flavour, texture, taste and overall acceptability of guava fruits during low temperature storage Figure 2. The highest scores were attributed to the fruits harvested at mature green stage and rated as 'like moderately' to 'like very much', over colour turning stage. However, peak scores were obtained with the CT stage fruits on 10^{th} day of storage. Sensory scores for fruit appearance and colour, flavour and taste increased until ripe stage, *i.e.* on 10^{th} day and 15^{th} day of storage with CT and MG stages respectively and then tend to decline till the end of storage. On the other hand, fruit texture gradually decreased with both the stages of maturity during storage. Gaur and Bajpai (1982) reported that organoleptic scores of pink stage tomato fruits were found superior over the red ripe fruits during storage.

There was a considerable loss in fruit quality due to inherent biochemical changes and also decay caused by various micro organisms during prolonged storage at 10 ± 1^0C. Among the polyamine treatments, guava fruits treated with Spermine at both the concentrations (100ppm and 200ppm) recorded highest overall acceptance scores compared to Spermidine treatments. The superiority of Spermine over Spermidine could be due to the polycationic nature of Spermine in decreasing the respiration rate, wherein the sugar levels get accumulated over prolonged storage at 10 ± 1^0C (Kramer *et al*., 1991). However, control obtained highest sensory score after 10 days of storage and the fruits were rated as "very much acceptable" but thereafter rapid decline in sensory quality was noticed and fruits registered a score below 5.5 (unacceptable) after 15 and 20 days of storage. This sharp decline in sensory quality of fruits in control may perhaps be due to over-ripening and early senescence resulting in excessive softening, off flavour, poor taste and dull appearance of the fruits. The improvement in palatability rating of various fruits with polyamine application has been reported by Bhagwan (1998) in tomato and Malik and Singh (2005) in mango. On the other hand, there are reports in contrary to the present findings. Purwoko *et al*. (1996) in papaya and mango reported that PAs treated fruits are inferior in organoleptic quality than control. However, explaining the discrepancies among the results from previous studies is rather difficult.

CONCLUSIONS

The stage of maturity or ripeness at harvest and postharvest treatments with polyamines had a significant effect in delaying ripening related changes in guava fruits during storage at 10 ± 1^0C and 90±5% RH. However, maturity stage at harvest strongly influenced the ripening behaviour of guava fruits as evidenced by changes in skin colour, firmness, percent ripening, percent spoilage, respiration and ethylene production rates. It is concluded that freshly harvested mature green guava fruits treated with Spermine (100ppm) can be stored for more than 24 days during cold storage with moderately acceptable fruit quality. It seems to be the best option if the fruits are to be transported to distant markets or stored for longer period. Furthermore, it may be suggested that CT stage guava fruits should not be stored for more than 10 days at 10 ± 1^0C, because rapid loss in quality occurs at that temperature and the fruits become over-ripe and mealy with poor consumer acceptability.

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APPENDICES

Table 1: Effect of Maturity Stages and Polyamines on Fruit Firmness (Kg/Cm^2) and Skin Colour 'Hunter L' (Lightness) of Guava Fruits Cv. Lucknow-49 at Low Temperature Storage

Maturity Stages	Storage Period (Days)									
	Firmness (Kg/cm^2)					Hunter 'L'				
	5	10	15	20	Mean	5	10	15	20	Mean
Mature Green stage (S1)	7.72^{a}	5.79^{a}	4.39^{a}	2.77^{a}	**5.17^{a}**	36.19^{a}	39.63^{a}	46.68^{a}	53.46^{a}	**43.99^{a}**
Colour Turning stage (S2)	6.42^{b}	4.85^{b}	3.24^{b}	1.68^{b}	**4.05^{b}**	45.47^{b}	49.37^{b}	54.80^{b}	57.31^{b}	**51.74^{b}**
Polyamine Treatments										
Spermidine - 100ppm (T1)	6.92^{d}	5.24^{cd}	3.74^{cd}	2.25^{cd}	**4.54^{d}**	41.68	45.57	51.64	57.83	**49.18^{d}**
Spermidine - 200ppm (T2	7.15^{bc}	5.37^{bc}	3.92^{bc}	2.40^{bc}	**4.71^{c}**	40.94	43.19	49.74	55.60	**47.37^{bc}**
Spermine - 100ppm (T3)	7.29^{ab}	5.50^{b}	4.07^{ab}	2.55^{ab}	**4.85^{b}**	39.52	42.14	48.80	53.79	**46.06^{ab}**
Spermine - 200ppm (T4)	7.42^{a}	5.73^{a}	4.27^{a}	2.62^{a}	**5.01^{a}**	37.72	41.09	46.97	52.92	**44.67^{a}**
Control (T5)	6.59^{e}	4.78^{e}	3.10^{e}	1.29^{e}	**3.94^{e}**	44.30	50.52	56.55	56.77	**52.04^{e}**
Mean	**7.07^{a}**	**5.32^{b}**	**3.82^{c}**	**2.22^{d}**		**40.83^{a}**	**44.50^{b}**	**50.74^{c}**	**55.38^{d}**	

Table 2

	S.Em±	C.D (0.05)	S.Em±	C.D (0.05)
Maturity Stages (MS)	0.024	0.068	0.353	0.993
Polyamine Treatments (PT)	0.038	0.108	0.558	1.571
Storage Period (SP)	0.034	0.097	0.499	1.405
MS × PT	0.054	NS	0.790	NS
MS × SP	0.049	0.137	0.706	1.987
PT × SP	0.077	0.216	1.117	NS
MS × PT × SP	0.109	NS	1.580	NS

Table 3: Effect of Maturity Stages and Polyamines on Skin Colour 'Hunter A' (Greenness) and 'Hunter B' (Yellowness) of Guava Fruits Cv. Lucknow-49 at Low Temperature Storage

Maturity Stages	Storage Period (Days)									
	Hunter 'a'					Hunter 'b'				
	5	10	15	20	Mean	5	10	15	20	Mean
Mature Green stage (S1)	-8.59^{a}	-5.53^{a}	-2.10^{a}	2.51^{a}	**-3.43^{a}**	19.19^{a}	23.42^{a}	28.32^{a}	35.00^{a}	**26.48^{a}**
Colour Turning stage (S2)	-6.44^{b}	-3.55^{b}	-0.39^{b}	4.03^{b}	**-1.59^{b}**	28.57^{b}	31.94^{b}	37.74^{b}	38.93^{b}	**34.30^{b}**
Polyamine Treatments										
Spermidine - 100ppm (T1)	-7.54^{cd}	-4.77^{cd}	-1.80^{d}	3.21^{d}	**-2.73^{d}**	24.79^{cd}	28.52^{cd}	35.74^{d}	36.46^{abcd}	**31.38^{d}**
Spermidine - 200ppm (T2	-7.60^{c}	-4.95^{bc}	-2.03^{bc}	2.85^{c}	**-2.93^{c}**	23.11^{bc}	26.60^{bc}	32.90^{c}	36.41^{ab}	**29.75^{c}**
Spermine - 100ppm (T3)	-7.95^{ab}	-5.11^{ab}	-2.23^{ab}	2.64^{b}	**-3.16^{b}**	21.34^{ab}	24.79^{ab}	30.79^{b}	36.42^{abc}	**28.33^{b}**
Spermine - 200ppm (T4)	-8.13^{a}	-5.20^{a}	-2.42^{a}	2.36^{a}	**-3.35^{a}**	20.06^{a}	23.10^{a}	28.05^{a}	35.40^{a}	**26.65^{a}**
Control (T5)	-6.35^{e}	-2.68^{e}	2.26^{e}	5.30^{e}	**-0.37^{e}**	30.10^{e}	35.40^{e}	37.68^{de}	40.14^{e}	**35.83^{e}**
Mean	**-7.51^{a}**	**-4.54^{b}**	**-1.24^{c}**	**3.27^{d}**		**23.88^{a}**	**27.68^{b}**	**33.03^{c}**	**36.96^{d}**	

Table 4

	S.Em±	C.D (0.05)	S.Em±	C.D (0.05)
Maturity Stages (MS)	0.022	0.062	0.232	0.652
Polyamine Treatments (PT)	0.035	0.098	0.366	1.030
Storage Period (SP)	0.031	0.088	0.328	0.922
MS × PT	0.049	NS	0.518	1.457
MS × SP	0.044	0.124	0.463	1.303
PT × SP	0.070	0.196	0.733	2.061
MS × PT × SP	0.099	0.278	1.036	2.915

Table 5: Effect of Maturity Stages and Polyamines on Skin Colour, 'Hue Angle' and 'Chroma' of Guava Fruits Cv. Lucknow-49 at Low Temperature Storage

Maturity Stages	Storage Period (Days)									
	Hue Angle					Chroma				
	5	10	15	20	Mean	5	10	15	20	Mean
Mature Green stage (S1)	65.23	76.12	84.35	86.00	**77.93**	21.10	24.13	28.46	35.10	**27.20**
Colour Turning stage (S2)	76.95	83.34	87.51	84.05	**82.96**	29.32	32.16	37.78	39.16	**34.61**
Polyamine Treatments										
Spermidine - 100ppm (T1)	70.73	78.93	86.10	85.54	**80.33**	24.46	27.12	32.99	36.52	**30.27**
Spermidine - 200ppm (T2	72.26	80.08	86.86	84.96	**81.04**	26.01	28.96	35.80	36.61	**31.85**
Spermine - 100ppm (T3)	66.87	76.42	84.63	86.31	**78.56**	21.79	23.77	28.18	35.48	**27.30**

Table 5: Contd.,										
Spermine - 200ppm (T4)	68.19	77.84	85.44	85.92	**79.35**	22.95	25.37	30.89	36.52	**28.93**
Control (T5)	77.42	85.37	86.64	82.40	**82.96**	30.84	35.52	37.75	40.50	**36.15**
Mean	**71.09**	**79.73**	**85.93**	**85.02**		**25.21**	**28.15**	**33.12**	**37.13**	

Table 6

	S.Em±	C.D (0.05)	S.Em±	C.D (0.05)
Maturity Stages (MS)	0.097	0.274	0.228	0.642
Polyamine Treatments (PT)	0.154	0.433	0.361	1.015
Storage Period (SP)	0.137	0.387	0.323	0.908
MS × PT	0.217	0.612	0.510	1.436
MS × SP	0.194	0.547	0.456	1.285
PT × SP	0.308	0.866	0.722	2.031
MS × PT × SP	0.435	1.224	1.021	2.873

Table 7: Effect of Maturity Stages and Polyamines on Ripening (%) and Spoilage (%) of Guava Fruits Cv. Lucknow-49 at Low Temperature Storage

Maturity Stages	Storage Period (Days)									
	Ripening (%)					Spoilage (%)				
	5	10	15	20	Mean	5	10	15	20	Mean
Mature Green stage (S1)	21.33^{a}	44.89^{a}	68.89^{a}	97.33^{a}	**58.11^{a}**	6.67^{a}	15.56^{a}	33.78^{a}	69.33^{a}	**31.33^{a}**
Colour Turning stage (S2)	40.44^{b}	73.79^{b}	97.78^{b}	100.00^{b}	**78.00^{b}**	9.33^{b}	20.89^{b}	43.56^{b}	84.89^{b}	**39.67^{b}**
Polyamine Treatments										
Spermidine - 100ppm (T1)	33.34^{cd}	63.34^{cd}	84.45^{cd}	100.00^{bc}	**70.28^{d}**	10.00^{cd}	21.11^{cd}	43.33^{d}	86.67^{d}	**40.28^{d}**
Spermidine - 200ppm (T2	30.00^{bc}	60.00^{c}	83.34^{c}	100.00^{bc}	**68.33^{c}**	7.78^{abc}	18.89^{c}	38.89^{c}	80.00^{c}	**36.39^{c}**
Spermine - 100ppm (T3)	26.67^{b}	48.89^{ab}	76.67^{ab}	97.78^{ab}	**62.50^{b}**	5.56^{ab}	14.44^{ab}	31.11^{b}	63.33^{b}	**28.61^{b}**
Spermine - 200ppm (T4)	22.22^{a}	46.70^{a}	74.44^{a}	95.56^{a}	**59.73^{a}**	4.45^{a}	11.11^{a}	25.56^{a}	55.56^{a}	**24.17^{a}**
Control (T5)	42.22^{e}	77.78^{e}	97.78^{e}	100.00^{bc}	**79.44^{e}**	12.22^{de}	25.56^{e}	54.44^{e}	100.00^{e}	**48.06^{e}**
Mean	**30.89^{a}**	**59.34^{b}**	**83.33^{c}**	**98.67^{d}**		**8.00^{a}**	**18.22^{b}**	**38.67^{c}**	**77.11^{d}**	

Table 8

	2010		2011	
Maturity Stages (MS)	0.392	1.104	0.401	1.127
Polyamine Treatments (PT)	0.620	1.745	0.633	1.782
Storage Period (SP)	0.555	1.561	0.567	1.594
MS × PT	0.877	2.468	0.896	2.520
MS × SP	0.785	2.208	0.801	2.254
PT × SP	1.241	3.490	1.267	3.563
MS × PT × SP	1.755	4.936	1.791	5.039

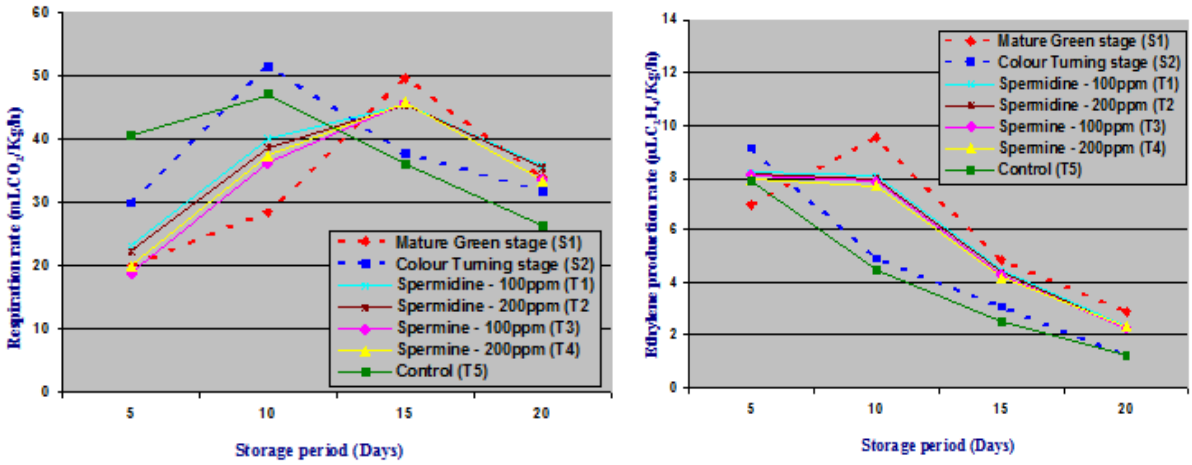

Figure 1: Effect of Maturity Stages and Polyamines on Respiration Rate ($Mlco_2$/Kg/H) and Ethylene Production Rate (μlc_2h_4/Kg/H) of Guava Fruits Cv. Lucknow-49 at Low Temperature Storage

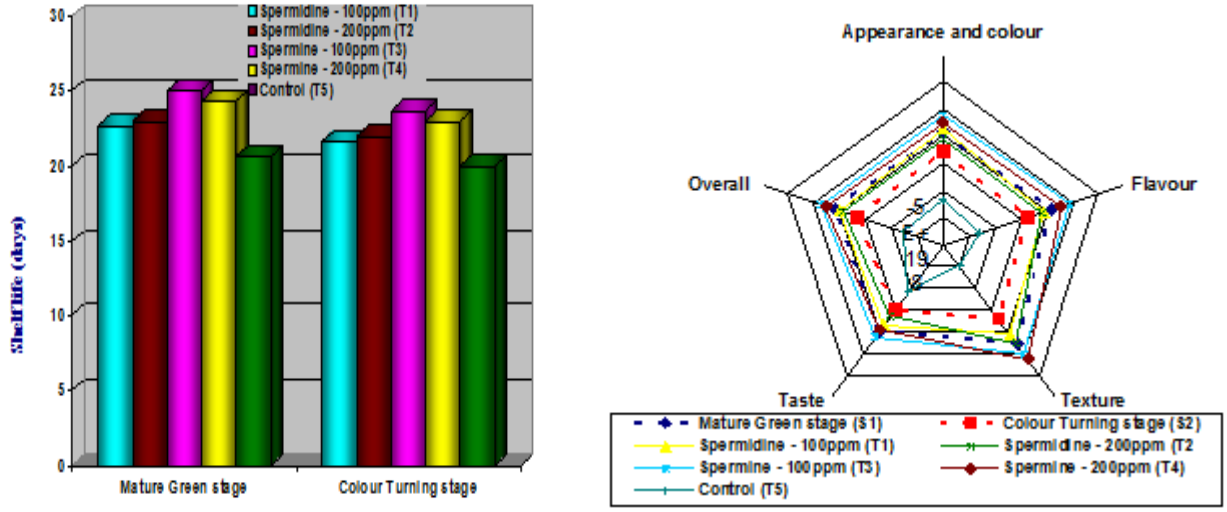

Figure 2: Effect of Maturity Stages and Polyamine Treatments on Shelf Life (Days) and Sensory Rating (9 Point Scale) for Appearance and Colour, Flavour, Texture, Taste and Overall Acceptance of Guava Fruits Cv. Lucknow-49 at Low Temperature Storage